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Hu

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[54] **ZERO CROSSING CIRCUIT FOR A RELAY**

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[73] Assignee: **The Watt Stopper**, Santa Clara, Calif.

[*] Notice: The term of this patent shall not extend beyond the expiration date of Pat. No. 5,640,113.

[21] Appl. No.: **821,117**

[22] Filed: **Mar. 19, 1997**

Related U.S. Application Data

[63] Continuation of Ser. No. 239,182, May 6, 1994, Pat. No. 5,640,113.

[51] **Int. Cl.**[6] **H03L 7/00**

[52] **U.S. Cl.** **326/162**; 327/141; 327/263

[58] **Field of Search** 327/141, 142, 327/143, 162, 163, 186, 198, 79, 104, 263, 267, 451; 361/3, 5, 8

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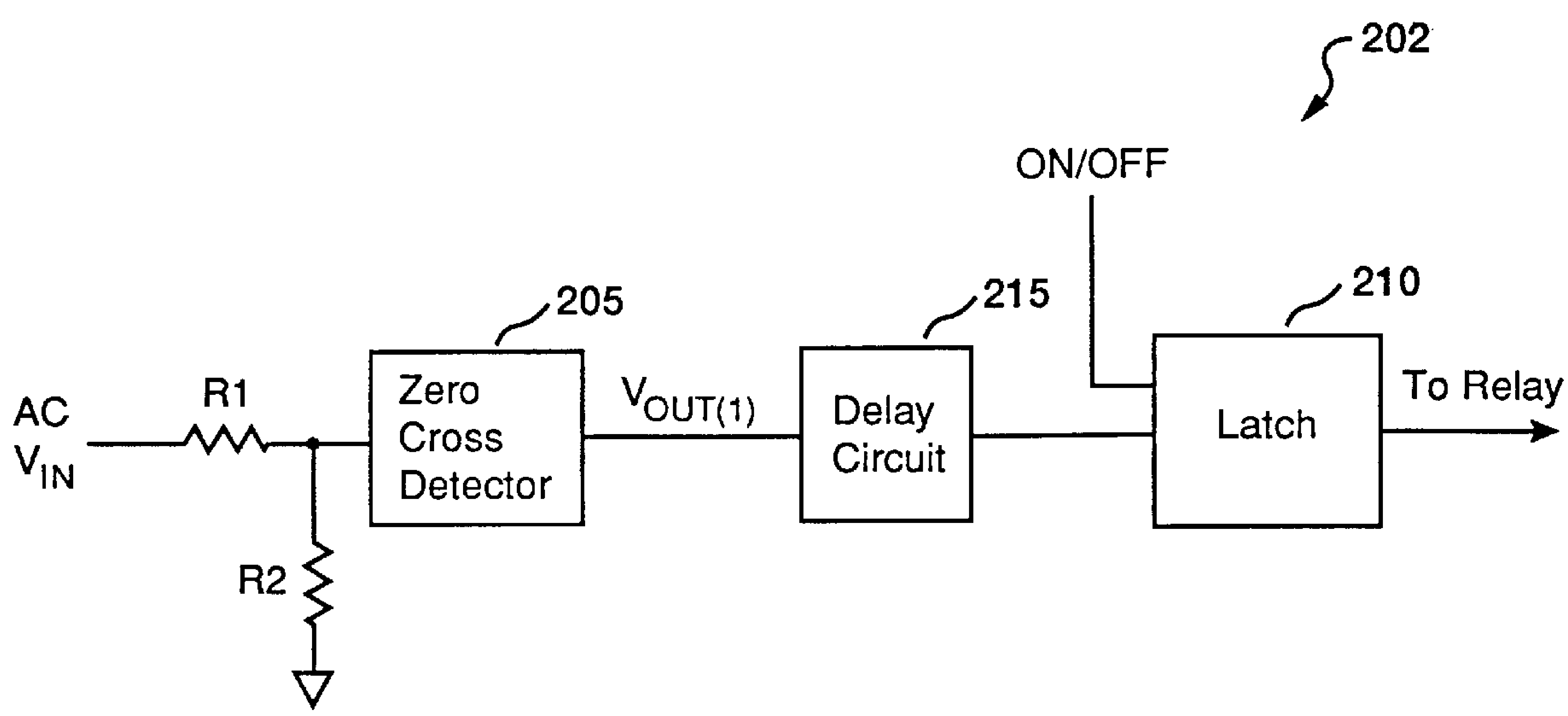
Primary Examiner—Toan Tran
Attorney, Agent, or Firm—Townsend and Townsend and Crew LLP

[57] **ABSTRACT**

A relay control circuit that includes a zero cross detector, a latch, and a delay circuit. The zero cross detector circuit detects when the voltage waveform or current waveform on an AC power line is at the zero crossing. The output of the zero cross detector clocks the latch (flip-flop), which receives a control signal at its data input. The flip-flop latches the control signal on the zero crossing point and outputs the latched signal to the delay circuit. The delay circuit delays the control signal for a predetermined time period depending on the make and break times of the relay so that the relay is switched ON and OFF substantially near the next zero crossing point of the AC voltage waveform.

8 Claims, 6 Drawing Sheets



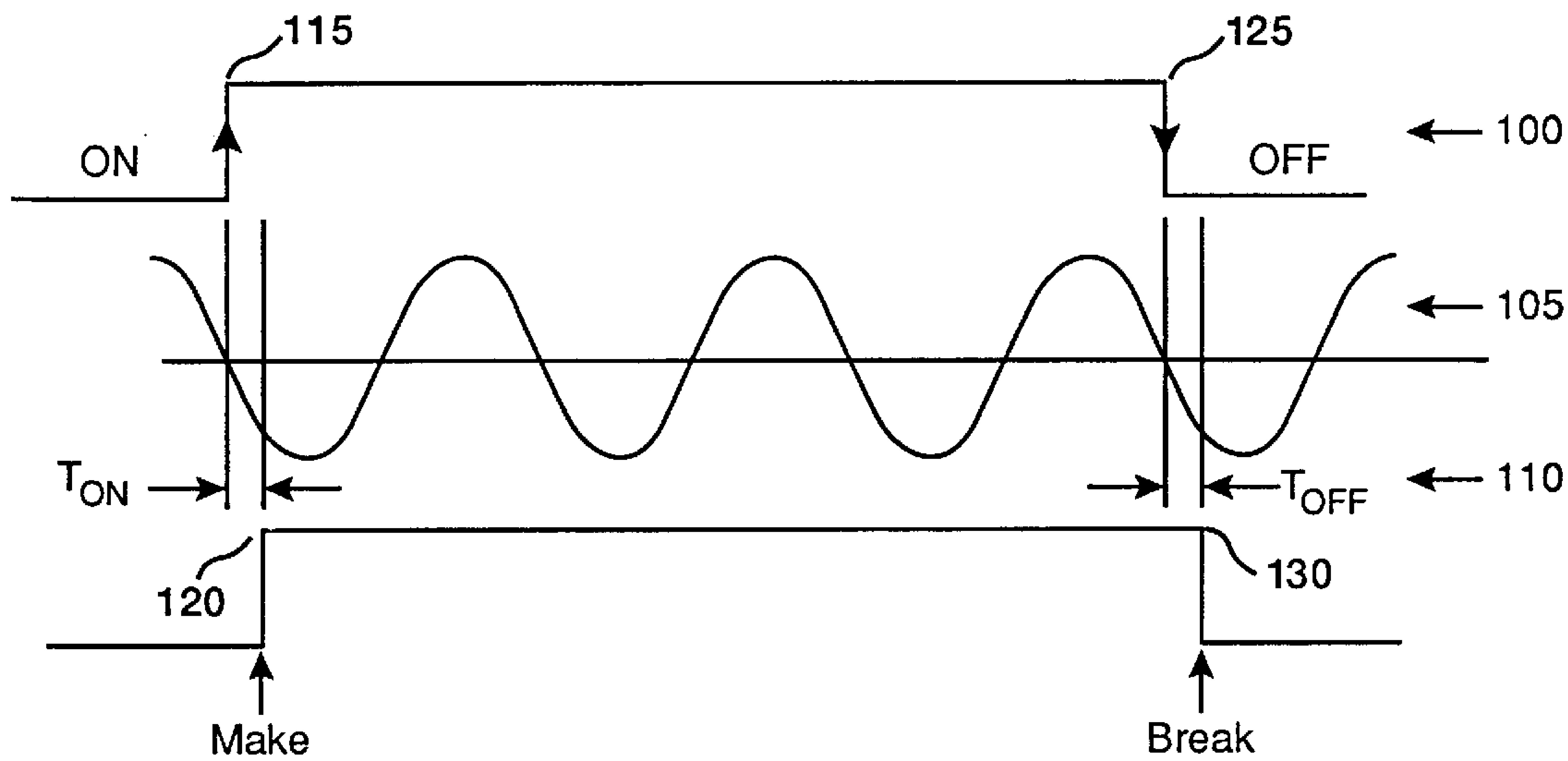

115
125
ON
OFF
100
105
110
TON
TOFF
120
130
Make
Break

Fig. 1

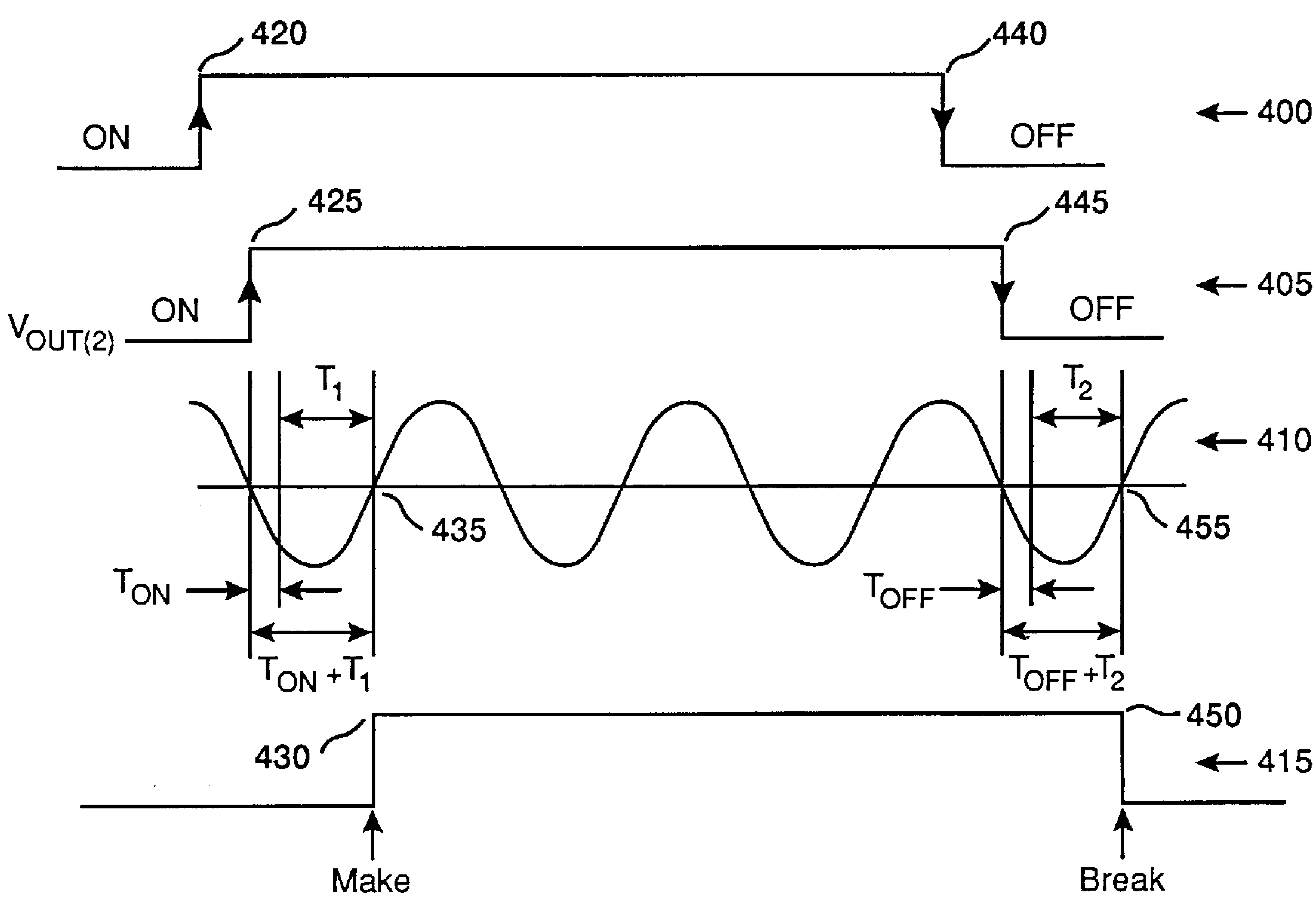

420
440
ON
OFF
400
425
445
VOUT(2)
ON
OFF
405
T1
T2
410
435
455
TON
TOFF
TON +T1
TOFF +T2
430
450
415
Make
Break

Fig. 4

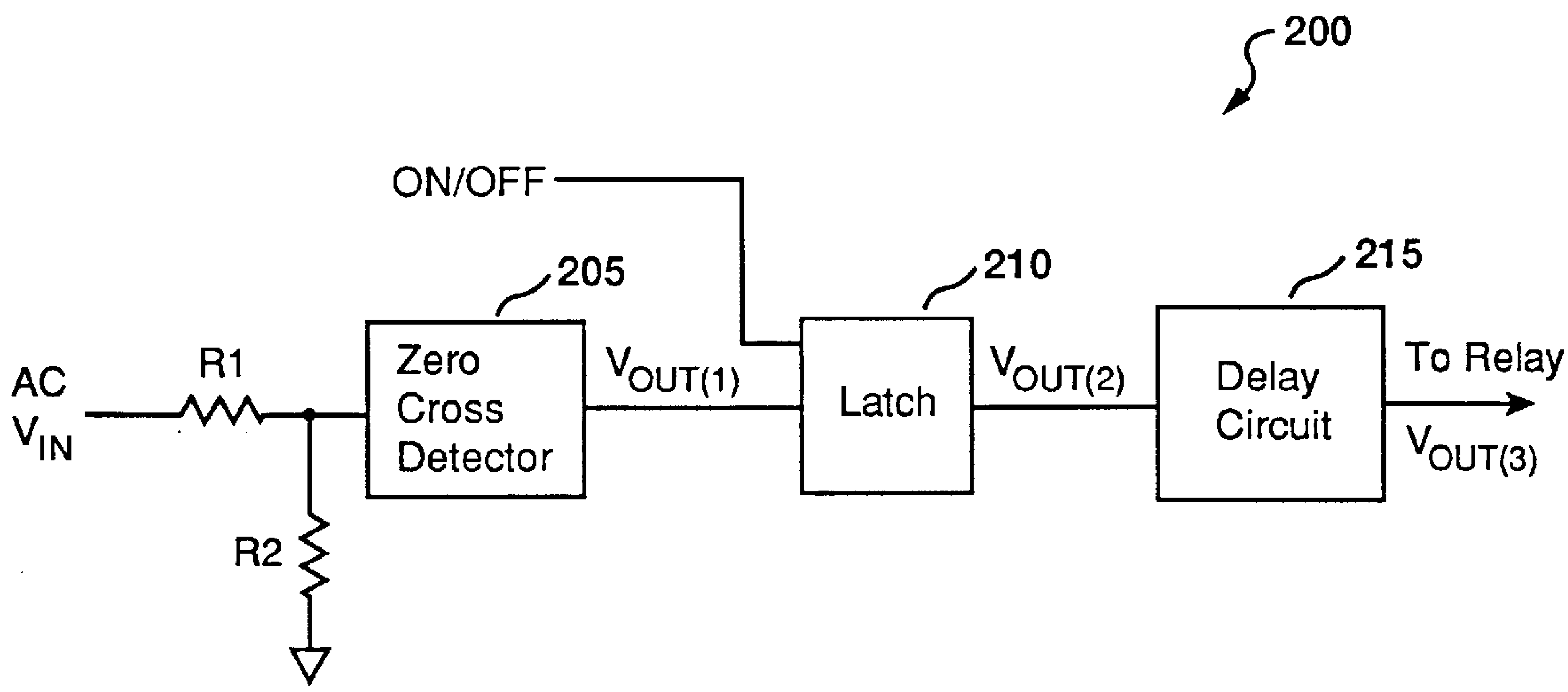

200
ON/OFF
205
210
215
AC
V_{IN}
R1
R2
Zero
Cross
Detector
$V_{OUT(1)}$
Latch
$V_{OUT(2)}$
Delay
Circuit
To Relay
$V_{OUT(3)}$

Fig. 2A

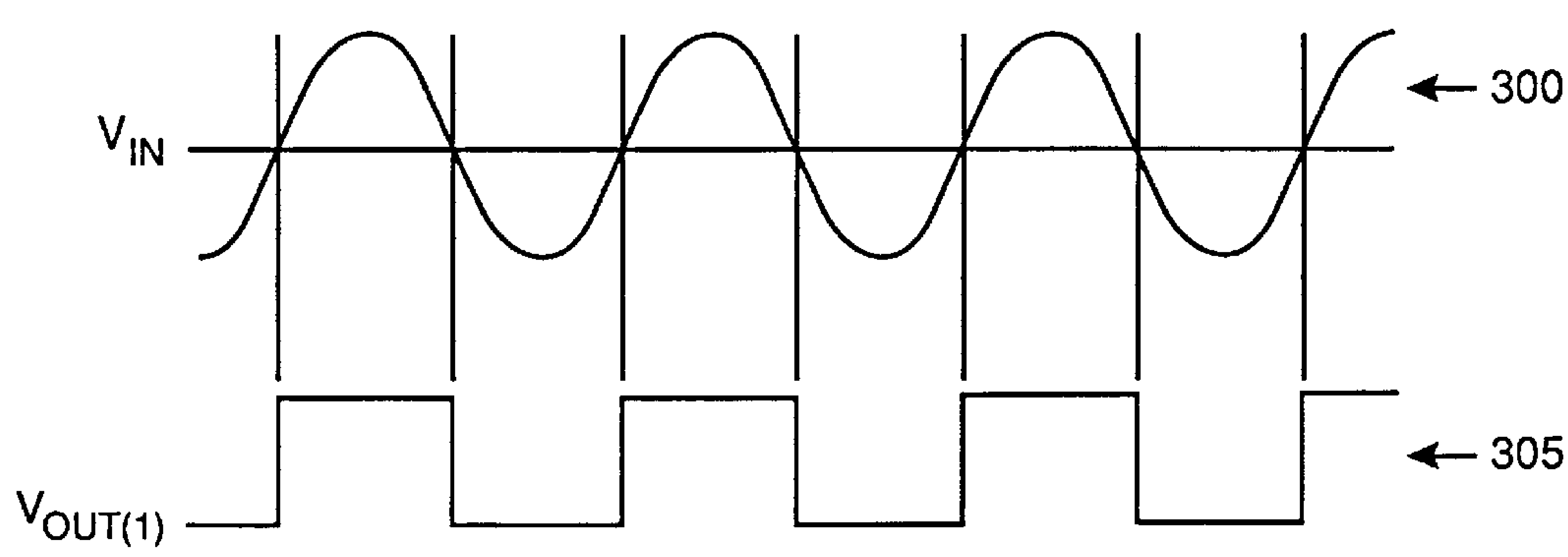

V_{IN}
300
$V_{OUT(1)}$
305

Fig. 3

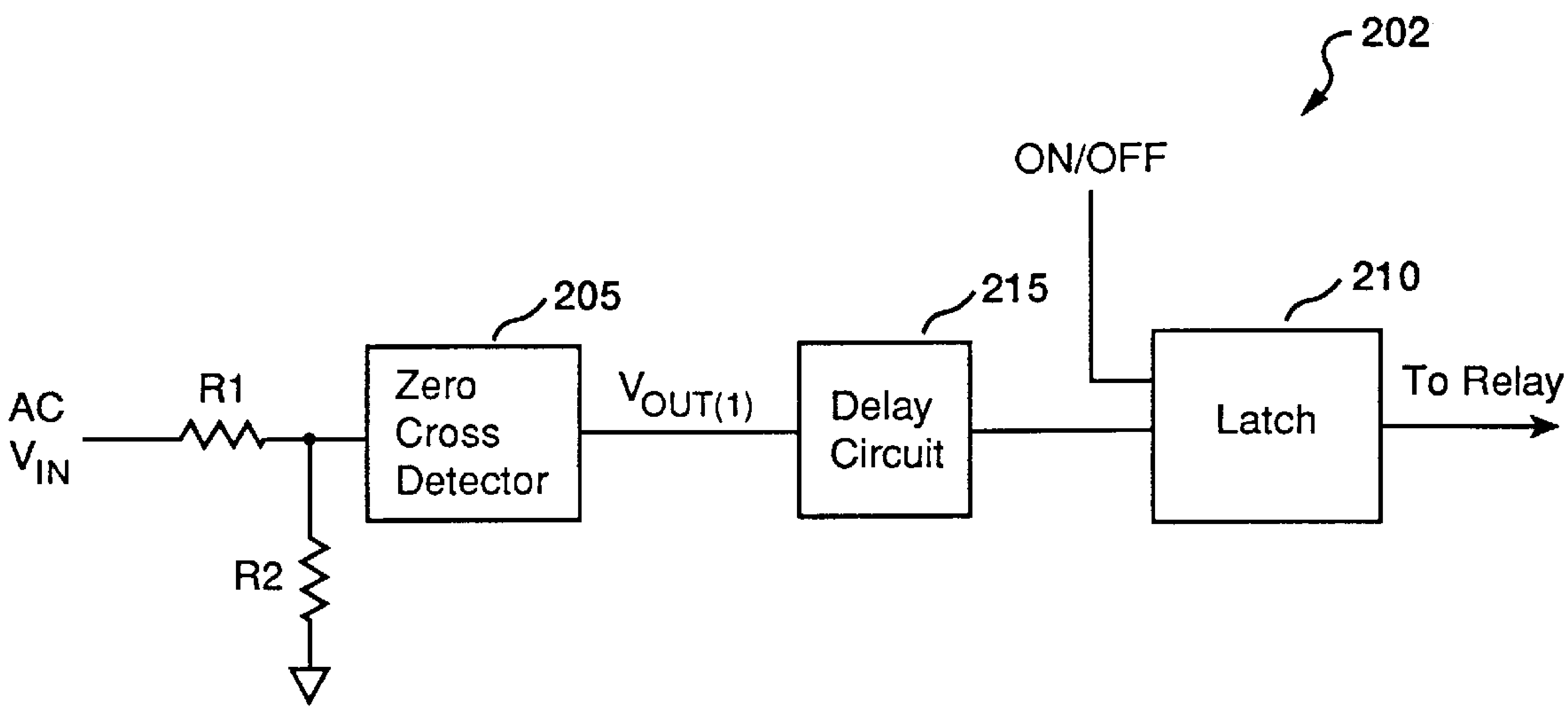

202
ON/OFF
205
215
210
AC
V_{IN}
R1
R2
Zero
Cross
Detector
$V_{OUT(1)}$
Delay
Circuit
Latch
To Relay

Fig. 2B

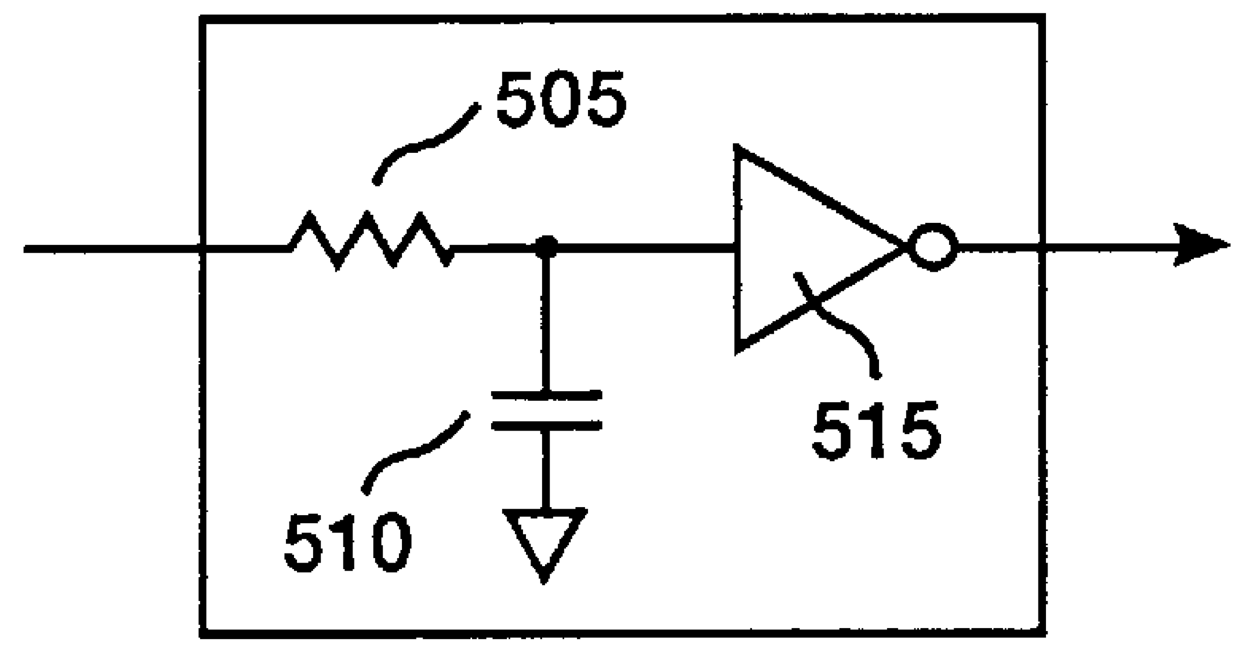


Fig. 5A

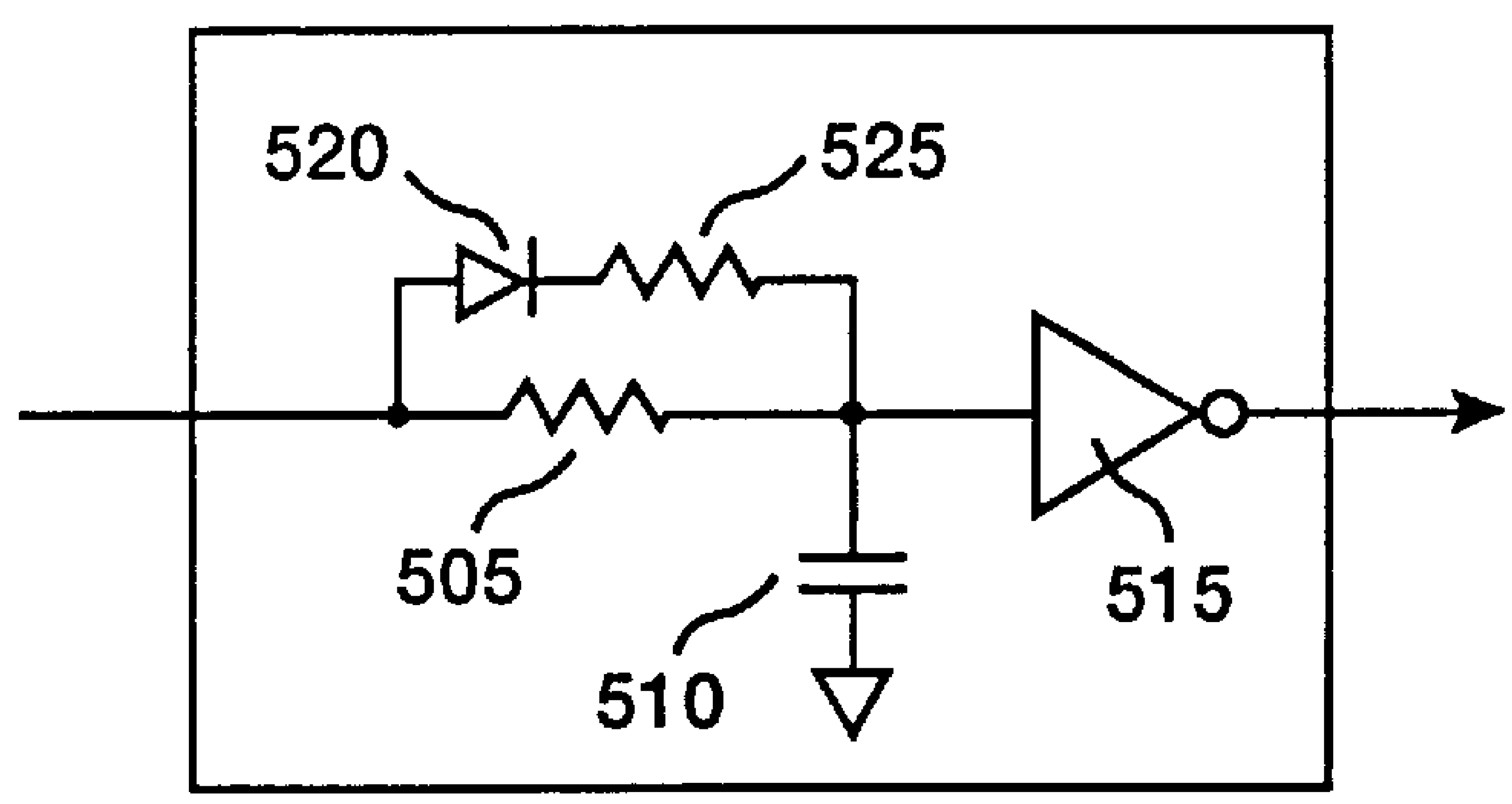


Fig. 5B

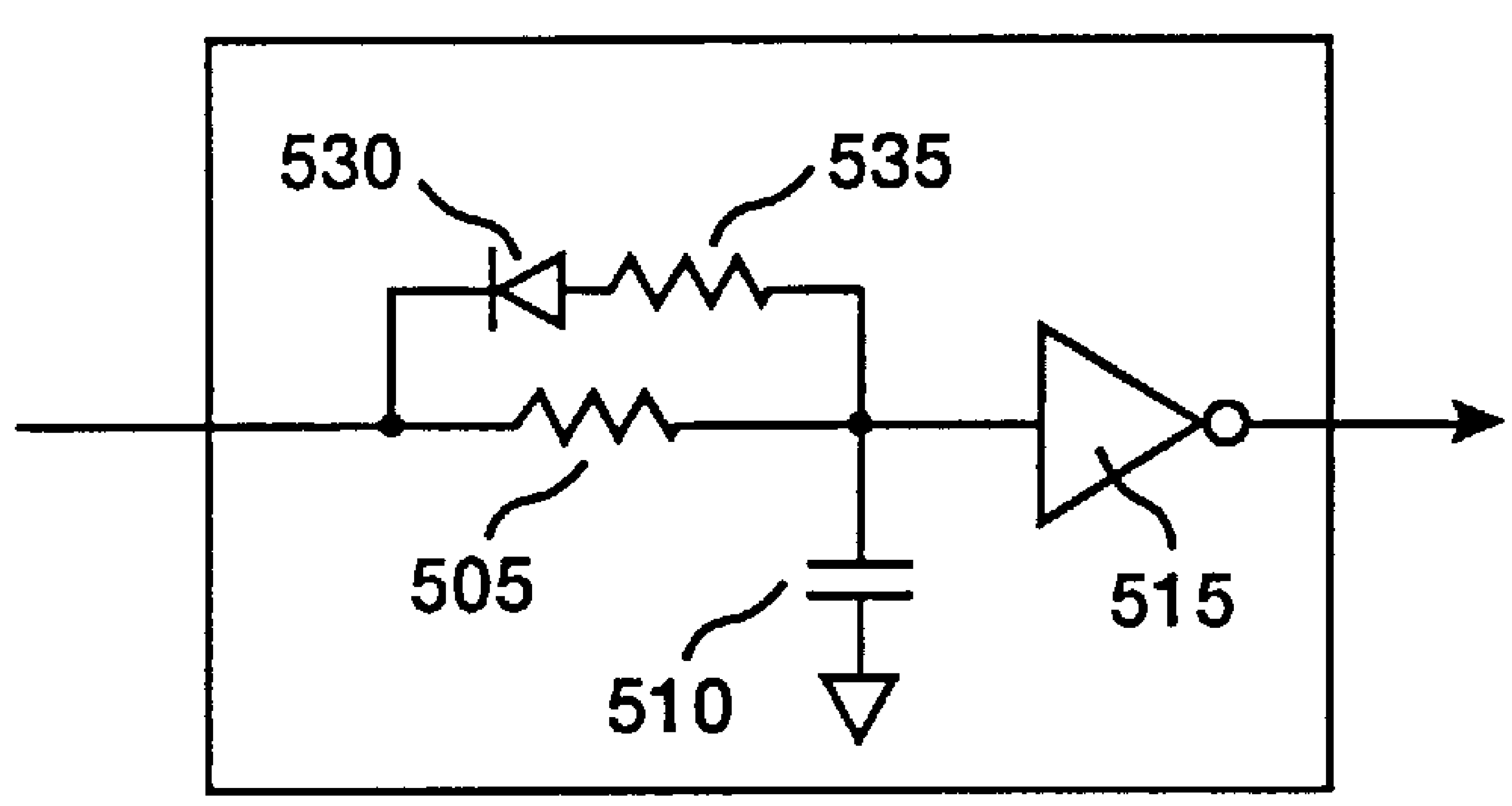


Fig. 5C

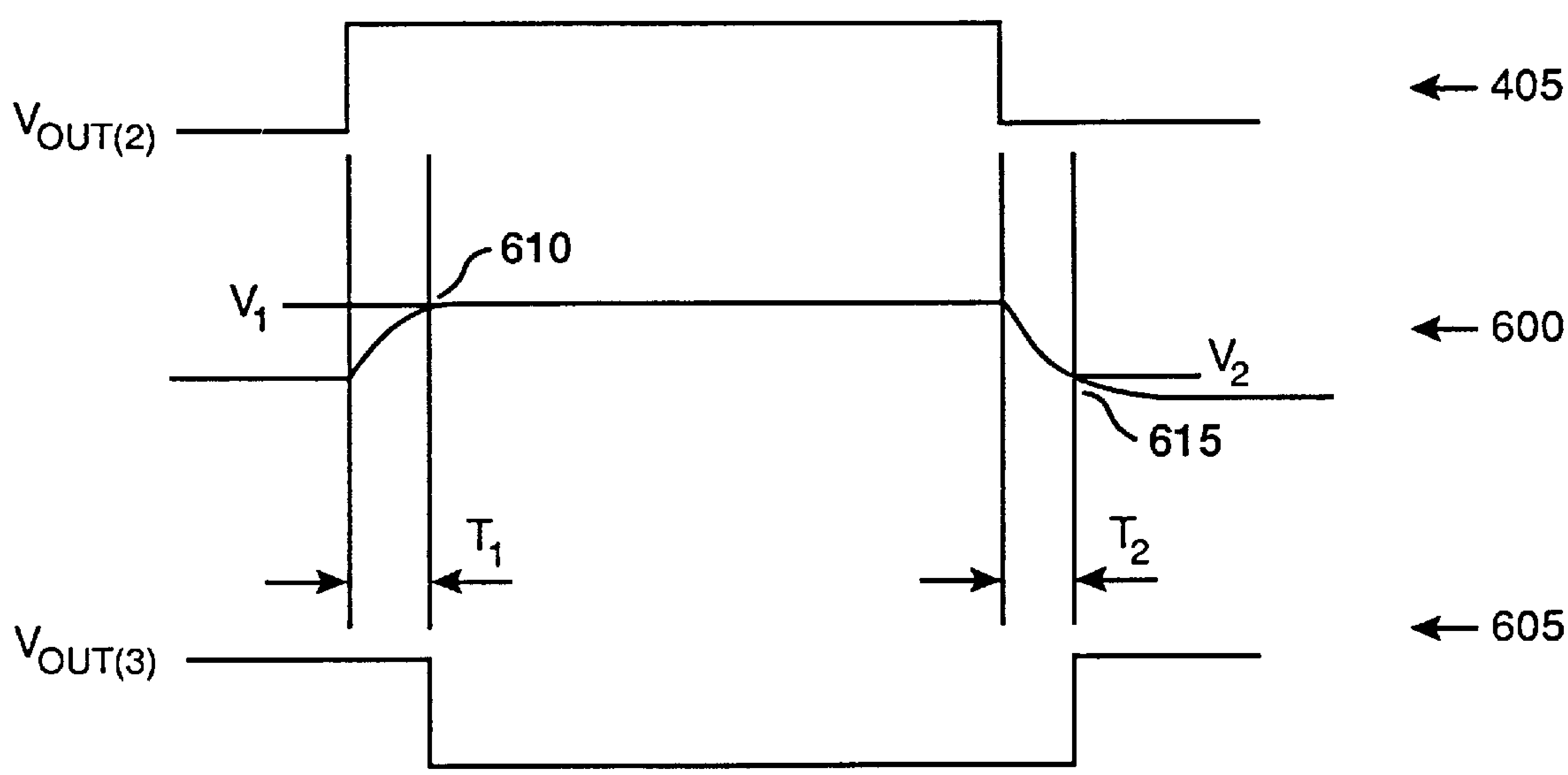


Fig. 6

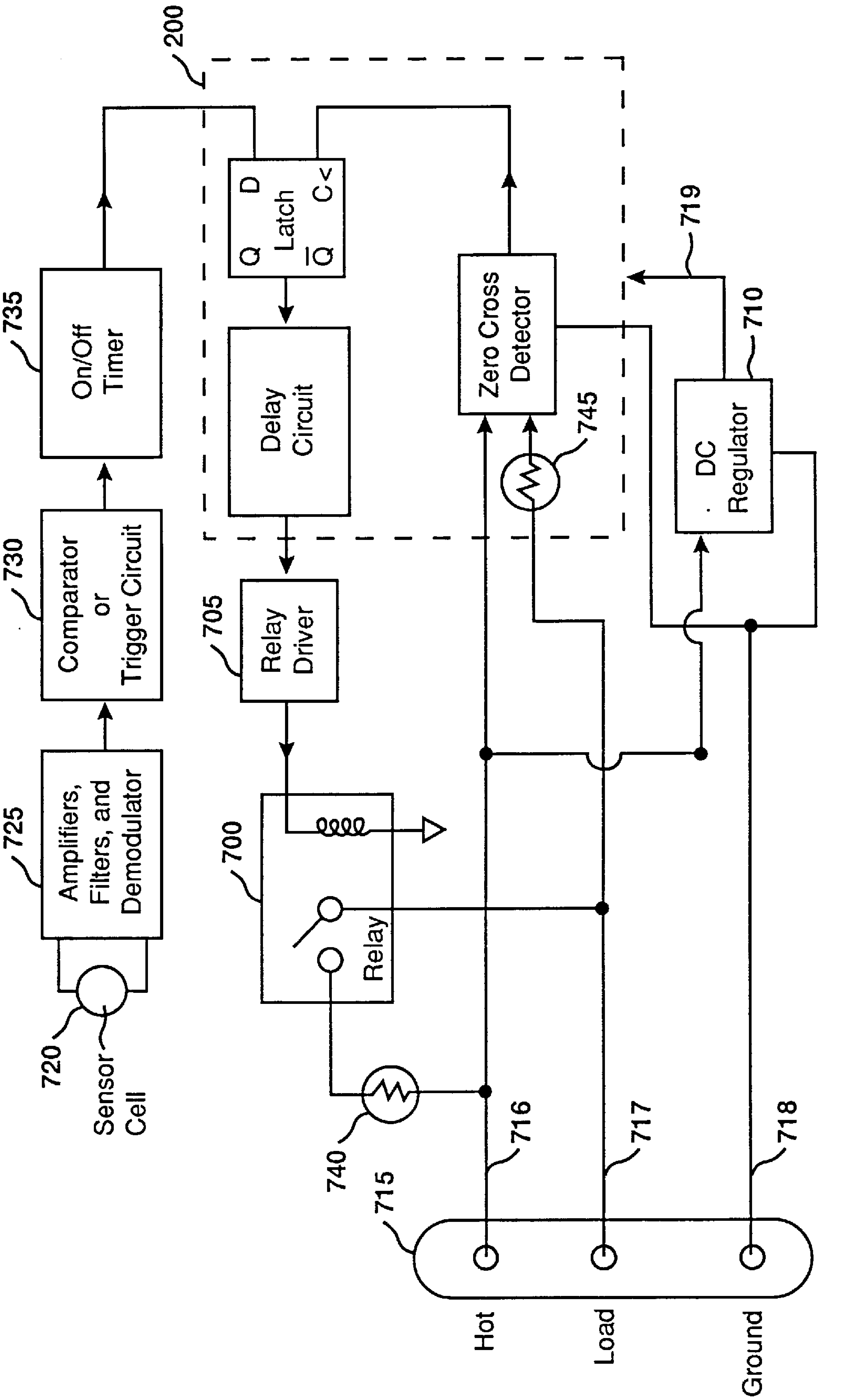

200
On/Off Timer
735
Comparator or Trigger Circuit
730
Amplifiers, Filters, and Demodulator
725
720
Sensor Cell
Q D Latch Q̄ C<
Delay Circuit
Zero Cross Detector
745
719
DC Regulator
710
Relay Driver
705
700
Relay
740
715
716
717
718
Hot
Load
Ground

Fig. 7

ZERO CROSSING CIRCUIT FOR A RELAY

This is a continuation of Application Ser. No. 08/239,182, filed May 6, 1994, now U.S. Pat. Ser. No. 5,640,113.

BACKGROUND OF THE INVENTION

The present invention relates to a method and apparatus for controlling the operation of a relay. More specifically, the present invention relates to a method and apparatus for switching a relay ON and OFF at or near the zero crossing point of an AC waveform.

Relays are used to switch many electrical appliances ON and OFF connecting and disconnecting the appliance from an AC power source, respectively, in response to a control signal. One category of electrical appliances that are commonly controlled by relays are electronic ballasts that are switched ON and OFF in response to a sensing device such as a motion detector.

When switching an electrical appliance such as an electronic ballast or an incandescent light ON and OFF with a relay, relay contact must be made at or near specific points along the AC voltage waveform—the zero crossing points. If contact is made or broken at random points along the AC voltage waveform, contact may be made when the waveform is at a sufficient voltage level to cause high temperature electrical arcs to form between the relay contacts. The formation of these arcs is referred to as arcing. Arcing causes contact erosion and reduces the useful service life of the relay.

A consideration that must be taken into account in designing a circuit that switches relays ON and OFF near the zero crossing point is the turn-on and turn-off time of the relay, also referred to as the "make" and "break" times of the relay, respectively. FIG. **1** is a timing diagram showing the delay that occurs in making and breaking relay contact. In FIG. **1**, an ON/OFF control signal **100**, an AC voltage waveform **105**, and a relay contact signal **110** are shown. When ON/OFF control signal **100** is switched to ON at point **115**, the delay in making relay contact at point **120** is shown by time T_{ON}. Since the voltage of waveform **105** is not near zero volts at point **120**, making relay contact at this point can damage the relay.

Similarly, when ON/OFF control signal **100** is switched to OFF at point **125**, the delay in breaking relay contact at point **130** is shown by time TOFF. Since the voltage of waveform **105** is not near zero volts at point **130**, breaking relay contact at this point can damage the relay. Many relays have make and break times that are equal to each other (T_{ON}=T_{OFF}). Other relays, however, have differing make and break times.

Previous circuits have been designed to account for the turn-on time of a relay and switch the relay on near the zero crossing point. One example of such a circuit is in U.S. Pat. No. 4,642,481 issued to Bielinski, et al. Another example is in U.S. Pat. No. 5,267,120 issued to Graff, et al. These prior art circuits, however, are complicated in both structure and number of components making them expensive to use on a mass production scale in highly competitive markets. Additionally, none of the prior art relay control circuits provide different delay times to ensure that relays which have different turn-on and turn-off times are both opened and closed at the zero crossing circuit.

SUMMARY OF THE INVENTION

The present invention solves the problems associated with the prior art by providing a simple and elegant circuit design that can ensure a relay is both turned ON and switched OFF at or near the zero crossing point.

In one embodiment of the present invention, a zero cross detector circuit detects when the voltage waveform on an AC power line is at the zero crossing. The output of the zero cross detector clocks a flip-flop, which receives a control signal at its data input. The flip-flop latches the control signal on the zero crossing point and outputs the latched signal to a delay circuit. The delay circuit delays the control signal for a predetermined time period depending on the make and break times of the relay so that the relay is switched ON and OFF substantially near the next zero crossing point of the AC voltage waveform. The zero cross detector circuit in this embodiment is referred to as a voltage sensing detector.

In another embodiment of the present invention, the zero cross detector circuit detects when the current waveform on an AC power line is at the zero crossing. This embodiment is particularly useful when the relay is controlling an inductive load, which has a low power factor. The zero cross detector circuit in this embodiment is referred to as a current sensing detector.

In still another embodiment of the present invention, the delay circuit delays the control signal for a first predetermined time period in relation to the make time of the relay and it delays the control signal for a second predetermined time period in relation to the break time of the relay.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a timing diagram showing the delay that occurs in making and breaking relay contact;

FIG. **2**A is a block diagram of one embodiment of the relay control circuit according to the present invention;

FIG. **2**B is a block diagram of one embodiment of the relay control circuit according to the present invention;

FIG. **3** is a timing diagram showing the AC voltage input to the zero cross detector shown in FIG. **2** and the voltage output from the zero cross detector;

FIG. **4** is a timing diagram showing where relay contact is made and broken when using the relay control to circuit shown in FIG. **2**.

FIG. **5**A is a circuit diagram of one embodiment of the delay circuit shown in FIG. **2**;

FIG. **5**B is a circuit diagram of a second embodiment of the delay circuit shown in FIG. **2**;

FIG. **5**C is a circuit diagram of a third embodiment of the delay circuit shown in FIG. **2**;

FIG. **6** is a timing diagram of the output of relay control circuit shown in FIG. **2** using the delay circuit shown in FIG. **5**A; and

FIG. **7** is a block diagram of the relay control circuit of the present invention being used with a light detector to switch an electronic ballast ON and OFF.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **2**A is a block diagram of one embodiment of a relay control circuit **200** according to the present invention. Relay control circuit **200** includes zero cross detector **205** for detecting whenever an AC voltage waveform crosses the zero voltage threshold, a latch **210** for latching an ON/OFF relay control signal, and a delay circuit **215** for delaying the latched ON/OFF relay control signal an appropriate period of time to switch the relay ON and OFF at or near the zero crossing level.

Zero cross detector **205** inputs an AC voltage waveform, V_{IN}, and produces an output signal that inverts on each zero crossing of the AC waveform. AC voltage waveform V_{IN} is reduced to an AC voltage waveform within the operating range of zero cross detector **205** by a voltage divider made up of resistors **R1** and **R2**. The reduced AC voltage waveform input to zero cross detector **205** is shown in FIG. **3**, which is a timing diagram showing the input to and output from zero cross detector **205**, as waveform **300**. The output of zero cross detector **205** is $V_{OUT(1)}$ and is also shown in FIG. **3** as waveform **305**.

As shown, zero cross detector **205** is a voltage sensing detector, which is most efficient when the relay switches loads having a high power factor ON and OFF. Zero cross detector **205** can also be a current sensing detector, however, which detects each zero crossing of an AC current waveform input to zero cross detector **205**. A current sensing detector is most efficient for controlling a relay that switches loads with low power factors, such as inductive loads, ON and OFF.

Referring back to FIG. **2**A, latch **210** is a D flip-flop which inputs at its data input an ON/OFF relay control signal and inputs at its clock input the output of zero cross detector **210**. Thus, latch **210** latches the relay control signal to zero crossing points of waveform **300**.

Delay circuit **215** delays the latched control signal so that the relay being controlled is switched ON and OFF at or near a zero crossing point. The amount of delay introduced by delay circuit **215** depends on the relay being controlled and is described in detail with respect to the various embodiments of delay circuit **215** shown in FIGS. **5***a–c*.

The operation of relay control circuit **200** is shown in FIG. **4**, which is a timing diagram showing when relay contact is made and broken in response to ON/OFF control signal **100**. In FIG. **4**, an ON/OFF control signal **400**, waveform **405** output from latch **210**, an AC voltage waveform **410**, and a relay contact signal **415** are shown. When ON/OFF control signal **400** is asserted ON at point **420**, latch **210** passes the control signal through its output timed with the zero crossing of AC waveform **410** as shown by point **425** of waveform **405**. Delay circuit **215** delays the output of latch **210** by time T_1, so that when the relay's turn-on time TON is added to T, relay contact is actually made at point **430** of waveform **415** at the next zero crossing point **435** of AC waveform **410**.

When ON/OFF control signal **400** is asserted OFF at point **440**, latch **210** passes the control signal through its output timed with the zero crossing of AC waveform **410** as shown by point **445** of waveform **405**. Delay circuit **215** delays the output of latch **210** by time T_2 so that when the relay's turn-off time T_{OFF} is added to T_1, relay contact is actually broken at point **450** of waveform **415** at the next zero crossing **455** of AC waveform **410**.

FIG. **5**A is a circuit diagram of one embodiment of delay circuit **215** shown in FIG. **2**A. In FIG. **5**A, delay circuit **215** includes a resistor **505**, a capacitor **510**, and an inverter **515**. The FIG. **5**A embodiment of delay circuit **215** works best with relays that have equal make and break times because it delays switching a relay ON the same amount of time as it delays switching a relay OFF. Thus, for the embodiment of delay circuit **215** shown in FIG. **5**A, delay time T, is equal to delay time T_2.

The amount of time making and breaking relay contact is delayed is determined by the chosen values of resistor **505** and capacitor **510** and calculated by R*C as is well known to those skilled in the art. The values of resistor **505** and capacitor **510** are chosen depending on the make and break times of the relay being controlled. The values do not need to be chosen so that relay contact is made and broken at exactly the zero crossing point every time, and in fact, because of slight variations in the resistance and capacitance of individual resistors and capacitors having contact made and broken at exactly the zero crossing point is impossible. The values should be chosen, however, so that relay contact is made/broken at least within ±44.4 degrees of the zero crossing point to ensure that the energy generated at contact is always less than the average energy that is generated if contact is randomly made and broken—70% peak value. Most preferably, values are chosen so that when resistor manufacturing tolerances are considered the make and break time of the controlled relay occurs within ±18 degrees of the zero crossing point. Ensuring that relay contact occurs within ±18 degrees ensures that the contact energy is less than 10% of its peak value.

FIG. **6** is a timing diagram of the output of relay control circuit **200** using delay circuit **215** shown in FIG. **5**A. For convenience, the same reference numbers used in FIG. **4** are used in FIG. **6** to refer to like waveforms. In FIG. **6**, waveform **405** is output from latch **210** to delay circuit **215**, waveform **600** is voltage waveform input to inverter **515**, and waveform **605** is the voltage waveform output from delay circuit **215**.

As shown in FIG. **6**A, when the rising edge of waveform **405** is input to delay circuit **215**, resistor **505** and capacitor **510** slow the rise of waveform **600**. Inverter **515** inverts its output when the voltage on waveform **600** increases to voltage level V_1 as indicated point **610**. The time it takes waveform **600** to raise to voltage level V_1 is indicated by time T_1 and represents the delay time delay circuit **215** delays the turn-on of the relay. Similarly, when the falling edge of waveform **405** is input to delay circuit **215**, inverter **515** inverts its output when the voltage on waveform **600** decreases to voltage level V_2 as shown by point **615**. The time it takes waveform **600** to decay to voltage level V_2 is indicated by time T_2 and represents the delay time delay circuit delays the turn-off of the relay. Thus, inverter **515** provides for a clean signal transition being output from delay circuit **215** to switch the relay ON and OFF.

FIG. **5**B is a circuit diagram of a second embodiment of delay circuit **215** shown in FIG. **2**A. For convenience, the same reference numerals used in FIG. **5**A are used in FIG. **5**B to refer to like elements. In FIG. **5**B, delay circuit **215** includes resistor **505**, capacitor **510**, inverter **515**, a diode **520**, and a resistor **525**. The FIG. **5**B embodiment of delay circuit **215** delays making relay contact a shorter period of time than it delays breaking relay contact. Thus, for the embodiment of delay circuit **215** shown in FIG. **5**B, delay time T_1 is less than delay time T_2.

When the output of latch **210** switches from low to high and capacitor **510** is being charged, current flows through resistor **525** and diode **520** as well as resistor **505**. Thus, the time delay introduced to make relay contact is determined mostly by the chosen values of resistor **505**, capacitor **510**, and resistor **525** in a manner well known to one skilled in the art (the voltage drop across diode **520** and other propagation delays are insignificant).

When the output of latch **210** switches from high to low and capacitor **510** is discharged, current flow through resistor **525** is blocked by diode **520**. Faced with greater resistance during the discharge cycle, the time delay T_2 is greater than the delay time T_1. The actual time delay introduced to break relay contact is determined by the values of resistor **505** and capacitor **510** in the same manner as described in relation to FIG. **5**A.

FIG. 5C is a circuit diagram of a third embodiment of delay circuit **215** shown in FIG. 2A. For convenience, the same reference numerals used in FIG. 5A are used in FIG. 5C to refer to like elements. In FIG. 5C, delay circuit **215** includes resistor **505**, capacitor **510**, inverter **515**, a diode **530**, and a resistor **535**. The FIG. 5C embodiment of delay circuit **215** delays making relay contact for a longer period of time than it delays breaking relay contact. Thus, for the embodiment of delay circuit **215** shown in FIG. 5B, delay time T_1 is greater than T_2.

When the output of latch **210** switches from low to high and capacitor **510** is being charged, current flow through resistor **535** is blocked by diode **530**, and thus, only flows through resistor **505**. Therefore, the time delay introduced to make relay contact is determined mostly by the chosen values of resistor **505** and capacitor **510** in the same manner as described in relation to FIG. 5A.

When the output of latch **210** switches from high to low and capacitor **510** is discharged, current flows through resistor **535** and diode **530** as well as resistor **505**. Faced with less resistance during the discharge cycle, the time delay T_2 is less than time delay T_1. The actual time delay introduced to break relay contact is determined by the values of resistor **505**, capacitor **510**, and resistor **535** in a manner well known to those skilled in the art.

FIG. **7** is a block diagram of relay control circuit **200** being used with a light detector to switch an electronic ballast ON and OFF. In addition to relay control circuit **200**, a relay **700**; a relay driver **705**; a DC regulator **710**; AC power line **715**, including a hot line **716**, a load line **717**, and a ground line **718**; a sensor cell **720**; an amplifier circuit **725**; a trigger circuit **730**; and timer **735** are shown in FIG. **7**.

In the operation of controlling an electronic ballast, shown as a load **740**, a 60 hertz, 120 volt AC power is received over AC power line **715**. The ballast is connected to AC power line **715** by hot line **716** and load line **717** through relay **700**. When relay **700** is closed, the ballast receives electricity and the light is switched ON. When relay **700** is open, the light is switched OFF.

DC regulator **710** provides a constant DC power supply to each of the elements in relay control circuit **200** over a signal path **719** and can also supply a constant DC power source to sensor cell **720**, amplifier **725**, trigger circuit **730**, and timer **735**, if necessary.

Sensor cell **720** detects occupancy of a room in which the ballast is situated. Signals from sensor cell **720** are filtered, amplified, and demodulated by amplifier circuit **725**, and trigger circuit **730** generates an ON signal from the amplified signal if the lights connected to the ballast should be switched ON. Finally, timer **735** generates a signal to switch the lights OFF if, after a predetermined time period, no motion is detected by sensor **720**.

The output trigger circuit **730** and timer **735** is input to relay control circuit **200**, which, in the manner described above, provides a signal to relay driver **705** that switches relay **700** ON and OFF.

As shown in FIG. **7**, relay control circuit **200** inputs both hot line **716** and load line **717** to zero cross detector **205**. Zero cross detector **205** can be either voltage sensing or current sensing. The zero crossing of the voltage level is sensed on hot line **716**, while the zero crossing of the current, which may lead the voltage if load **740** is inductive, is sensed on load line **717**. The current on load line **717** is converted to a voltage level by a current sensing device **745** such as a resistor or diode. A switch on zero crossing detector **205** can be used to allow selection between a voltage or current sensing zero cross detector, or optionally, circuitry could be included to detect if load **740** is inductive and thus has a low power factor. If the circuitry detects an inductive load, zero cross detector **205** could automatically adapt to a current sensing mode, while if the load has a high power factor, zero cross detector **205** could adapt a voltage sensing mode.

Of course, although FIG. **7** shows the present invention being used in a three wire AC power system, it can also be used with a two wire AC power system. In a two wire system, zero cross detector **205** senses voltage on the hot line and current on the neutral line.

Having fully described the preferred embodiments of the present invention, many other equivalent or alternative methods of implementing the relay control circuit will be apparent to those skilled in the art. For example, latch **210** can be implemented with flip-flops and latches other than a D flip-flop, and delay circuit **215** can be implemented with many different combinations of resistors, capacitors, operational amplifiers, and voltage comparators. Some or all of the various resistors in delay circuit **215** can potentiometers which can be tuned to different resistance levels depending on the relay controlled.

Additionally, delay circuit **215** can be situated between zero cross detector and latch **210** to delay clocked ON/OFF control signal **405** for a time period T_1 or T_2 so the T_{ON} or T_{OFF} represents delay between the output of latch **210** and making or breaking relay contact at a zero crossing point, respectively. A relay control circuit **202** of this type is shown in FIG. **2B**. For convenience, the same reference numerals used in FIG. **2A** are used in FIG. **2B** to refer to like elements. Zero cross detector **205** could produce a pulse each zero crossing of the AC waveform while latch **210** would be clocked on each pulse. These equivalents and alternatives are intended to be included within the scope of the present invention.

What is claimed is:

1. A relay control circuit for controlling an electromechanical relay which switches a circuit, said relay control circuit comprising:

(a) a zero cross detector for detecting when an AC signal crosses a zero-crossing point; and

(b) a delay element, coupled to said zero cross detector and coupled to a coil of the electromechanical relay, configured to delay a relay ON/OFF signal a predetermined period of time, said delay element including:

i) a flip-flop for latching said relay ON/OFF signal to produce a latched relay ON/OFF signal; and

ii) a delay circuit for delaying the latched relay ON/OFF signal said predetermined period of time wherein said flip-flop is coupled at an input to said zero cross detector and coupled at an output to said delay circuit, and wherein said predetermined time period is selected so that the electromechanical relay switches substantially at a zero-crossing point.

2. A relay control circuit to prevent arcing that occurs in an electromechanical relay when relay contact is made to an AC power line and the energy level on the AC power line is at an energy level other than zero, said relay control circuit comprising:

(a) a zero cross detector, coupled to the AC power line, for outputting a signal which indicates each time the energy level on the AC power line becomes zero;

(b) a flip-flop, coupled to said zero cross detector, which receives a control signal at a data input and receives the signal output from said zero cross detector at a clock input, for latching the control signal when the energy on the AC power line is zero to produce a latched control signal; and

(c) a delay circuit, coupled to an output of said flip-flop and coupled to a coil of the electromechanical relay, for delaying said latched control signal for a predetermined time period so that relay contact is made to the AC power line substantially near the zero-crossing level.

3. A method of switching an electromechanical relay ON and OFF substantially near the zero-crossing of an AC power line, said method comprising the steps of:

(a) detecting a first zero-crossing point on the AC power line;

(b) latching a relay control signal, using a flip-flop, when said crossing point is detected to produce a latched relay control signal;

(c) delaying said latched relay signal a predetermined amount of time selected in dependence on a make time of the electromechanical relay, thereby creating a delayed latched signal; and

(d) supplying said delayed latched signal to a coil of the electromechanical relay, thereby causing the electromechanical relay to switch ON substantially near a second zero-crossing point.

4. A relay control circuit for controlling an electromechanical relay that switches a light coupled to an electronic ballast ON and OFF in response to a control signal from a motion detector, said relay control circuit comprising:

(a) a zero cross detector for detecting when an AC power signal powering said light crosses a zero-crossing point; and

(b) a delay element, coupled to said zero cross detector and coupled to a coil of the electromechanical relay, configured to delay said control signal a predetermined period of time so that relay contact is made and broken substantially near a zero-crossing point, said delay element including:

i) a flip-flop for latching said control signal, said latching of said control signal producing a latched control signal; and

ii) a delay circuit for delaying said latched control signal said predetermined period of time, wherein said flip-flop is coupled between said zero cross detector and said delay circuit.

5. A relay control circuit for controlling an electromechanical relay which switches a circuit comprising:

(a) a zero cross detector for detecting when an AC signal crosses a zero-crossing point; and

(b) a delay element, coupled to said zero cross detector, configured to delay a relay ON/OFF signal a predetermined period of time, said delay element including:

i) a flip-flop for latching said relay ON/OFF signal; and

ii) a delay circuit for delaying the coupled at an input to said zero cross detector and at an output to said flip-flop, for producing a pulse for clocking said flip-flop to change state after each zero-crossing.

6. A relay control circuit for controlling an electromechanical relay which switches a circuit, said relay control circuit comprising:

(a) a zero cross detector for detecting when an AC signal crosses a zero-crossing point; and

(b) a delay element, coupled to said zero cross detector and coupled to a coil of the electromechanical relay, configured to delay a relay ON/OFF signal a predetermined period of time, said delay element including:

i) a flip-flop for latching said relay ON/OFF signal to produce a latched relay ON/OFF signal; and

ii) a delay circuit, coupled to an output of said flip-flop and coupled to a coil of the electromechanical relay, for delaying said latched relay ON/OFF signal said predetermined period of time, wherein said flip-flop comprises a D flip-flop, and

wherein said delay circuit comprises a first resistor and a capacitor, and a second resistor and a diode coupled in parallel with said first resistor.

7. A relay control circuit to prevent arcing that occurs when relay contact is made to an AC power line and the energy level on the AC power line is at an energy level other than zero, said relay control circuit comprising:

(a) a zero cross detector, coupled to the AC power line, for outputting a signal which indicates each time the energy level on the AC power line becomes zero;

(b) a flip-flop, coupled to said zero cross detector, which receives a control signal at a data input and receives the signal output from said zero cross detector at a clock input, for latching the control signal when the energy on the AC power line is zero, said latching of said control signal producing a latched control signal; and

(c) a delay circuit, coupled to an output of said flip-flop and coupled to a coil of the electromechanical relay, for delaying said latched control signal for a predetermined time period so that relay contact is made to the AC power line substantially near the zero-crossing level, wherein said delay circuit comprises a first resistor and a capacitor, and

wherein said delay circuit further comprises an inverter coupled at an input to said first resistor and said capacitor.

8. A method of switching an electromechanical relay ON and OFF substantially near the zero-crossing of an AC power line, said method comprising the steps of:

(a) detecting a first zero-crossing point on the AC power line;

(b) delaying a relay control signal after detecting said first zero-crossing point by a predetermined amount of time selected in dependence on a make time of the electromechanical relay, thereby creating a first delayed latched signal;

(c) supplying said first delayed latched signal to a coil of the electromechanical relay, thereby causing the electromechanical relay to switch ON substantially near a second zero-crossing point;

(d) detecting a third zero-crossing point on the AC power line;

(e) delaying the control signal a second predetermined amount of time depending on a break time of the electromechanical relay, thereby creating a second delayed latched signal; and

(f) supplying said second delayed latched signal to a coil of the electromechanical relay, thereby causing the electromechanical relay to switch OFF substantially near a fourth zero-crossing point.

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